National Bureau of Standards

TECHNICAL NEWS BULLETIN

VOLUME 38 JANUARY 1954 NUMBER 1

Radio Disturbance Warnings From WWVH

BEGINNING JANUARY 5, 1954, the National Bureau of Standards will broadcast short-term radio propagation forecasts for the North Pacific area from its standard frequency broadcasting station WWVH, the Hawaiian counterpart of the Bureau's Washington station, WWV. The disturbance notices tell users of radio transmission paths over the North Pacific the condition of the ionosphere at the time of the announcement and how good or bad communication conditions are expected to be for the next 12 hours. Forecasts are prepared three times daily by the Bureau's North Pacific Radio Warning Service at Anchorage, Alaska. Currently, only those forecasts issued at 8 a. m. and 4 p. m. (Alaska and Hawaiian time) are to be relayed to WWVH, on the island of Mauii, Territory of Hawaii.

The North Pacific forecasts issued by NBS apply only to short-wave radio transmissions over paths that are near the auroral zone for a considerable part of their length. In this zone the ionospheric layers are very likely to be disturbed, and because short-wave, long-range radio transmissions are dependent on the condition of the ionosphere, communications may be disrupted. Often the ionospheric disturbance accompanies intense magnetic field variations and a brilliant aurora. The resulting propagation effects range from severe fading to a complete break in the communications link. The NBS forecasts of propagation conditions for the next few hours supplement the more general forecasts made several days in advance and permit a more efficient utilization of the short-wave radio spectrum for communications.

This forecasting service of the Bureau has been available since 1952 [1] to Government and private communication agencies throughout the North Pacific. Now that the notices are being broadcast by WWVH, the service also becomes available to remote outposts and to amateur radio operators. The forecasts apply to radio transmission in three service areas illustrated by the following typical paths: from Alaska to Seattle or San Francisco, from Alaska to the Aleutians and Tokyo, and within Alaska. The Bureau's North Pacific radio propagation warning services are similar to those NBS provides for communication paths across the North Atlantic.[2] Short-term forecasts for the North Atlantic are broadcast by the Bureau's standard-frequency radio station WWV near Washington.

The North Pacific short-term forecasts are transmitted by WWVH in Morse Code twice each hour—9 and 39 minutes past the hour—on standard frequencies of 5, 10, and 15 Mc. By contrast the North Atlantic forecasts are broadcast on these same frequencies by WWV at 19½ and 49½ minutes past the hour. The announcement consists of a letter and a digit. The digit is the forecast of the radio propagation quality on typical North Pacific transmission paths during the 12 hours after the forecast is made. The numbering system is based on a scale of 1 (useless) through 5 (fair) to 9 (excellent). The announcement is repeated every half hour until the next forecast is issued.

The letter portion of the forecast announcement identifies the radio quality at the time the forecast is made at the Bureau's forecasting station in Anchorage. The letters denoting quality are "N", "U", and "W", signifying that radio propagation conditions are normal, unsettled, and disturbed, respectively. If, for

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example, propagation conditions are good at the time the forecast is made, but an important disturbance is expected during the next 12 hours, the forecast would be broadcast as N3 in Morse Code, repeated three times, i. e., "N3, N3, N3".

The selection of WWVH to broadcast the propagation forecasts was based on several factors. For one, it operates on a regular schedule and transmits simultaneously three standard radio frequencies—5, 10, and 15 Mc. Because Hawaii lies well outside the region of severe ionospheric disturbances, the WWVH, broadcasts can be heard with excellent reliability throughout the Pacific area. WWVH is easily recognizable because each of the standard radio frequencies is modulated by standard audio frequencies of 440 and 600 cycles during alternate four minute periods. Time intervals of precisely one second—seconds ticks—are also broadcast. WWVH broadcasts 52 minutes each hour except for prescribed maintenance periods.[3]

The NBS forecasting program is made possible because of the cooperation of many Government agencies and several private organizations that provide ionospheric data and communications information. Reports are received regularly from points throughout the North Pacific area, Japan, and Canada. The Anchorage forecasting center is also associated with a worldwide network of solar and ionosphere observatories.[4] The information collected and disseminated through this network provides some of the basic data from which long-range forecasts are made both at Anchorage and at Washington.

Pictorial representation of part of the area served by National Bureau of Standards radio station WWV and WWVH for the dissemination of radio propagation disturbance forecasts in the North Pacific and the North Atlantic. The U-shaped area at top is zone of greatest propagation disturbance. The forecasts tell users of radio the transmission paths across these areas, the condition of the ionosphere at the time of the announcement, and how good or bad communication conditions are expected to be for the next 12 hours. Forecasts for the North Pacific are prepared by the Bureau's North Pacific Warning Service at Anchorage, Alaska. The North Atlantic warnings are prepared by NBS in Washington, D. C. The reception of signals from the Bureau's standard-frequency broadcasting stations is dependent on frequency of transmission, time of day, season, and the condition of the ionosphere.

With the inauguration of the Bureau's North Pacific broadcast service, forecasts of expected short-term radio propagation conditions are available over most of the northern hemisphere.

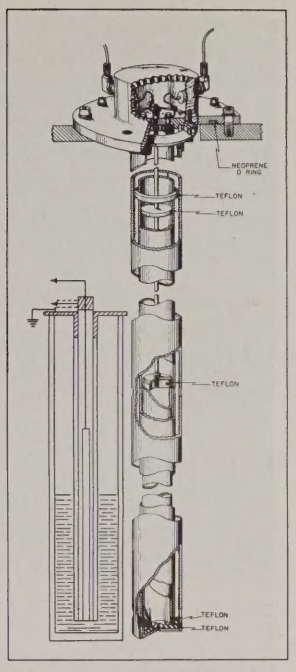
[1] North Pacific Radio Warning Service, NBS Technical News Bulletin **36,** 33 (March 1952).
[2] New Radio Propagation Disturbance Warnings, NBS Technical News Bulletin **36,** 95 (June 1952).
[3] WWVH transmission schedules are described in NBS Letter Circular LC1009, available on request.
[4] World Wide Observations of Solar Activity, NBS Technical News Bulletin **35,** 93 (July 1951).

Hydraulic Research

Hydraulic Research in the United States, edited by Helen K. Middleton and Sonya W. Matchett (National Bureau of Standards Miscellaneous Publication 208), contains information compiled annually from reports by the various hydraulic and hydrologic laboratories in the United States and Canada. Projects include private, university, and government supported research. Much of the work listed in this volume is reported for the first time. Order from Government Printing Office, Washington 25, D. C., $1.25.

LOW-TEMPERATURE LIQUID-LEVEL INDICATOR

for condensed gases



NBS sensing capacitor developed for use with liquefied gases at temperatures near absolute zero. The gage has no moving parts. A change in the capacitance of the tank is directly proportional to the change in liquid level and is detected and recorded through suitable electronic circuitry.

A LOW-TEMPERATURE INSTRUMENT that measures, indicates, records, and controls the level of liquefied gases such as hydrogen or nitrogen has recently been developed by W. E. Williams and E. Maxwell of NBS with the cooperation of the Brown Instrument Division of Minneapolis-Honeywell Regulator Co. This electronic instrument operates on the capacitance principle and makes use of the difference in dielectric constants of the liquid and vapor states. The sensing element is a vertical cylindrical capacitor whose capacitance is a function of the height of the liquid refrigerant column. The NBS instrument is designed to be used interchangeably with hydrogen, nitrogen, oxygen, or helium merely by changing the sensitivity and range controls on the associated electronic circuitry. It also incorporates a control system that maintains the liquid level at a predetermined point.

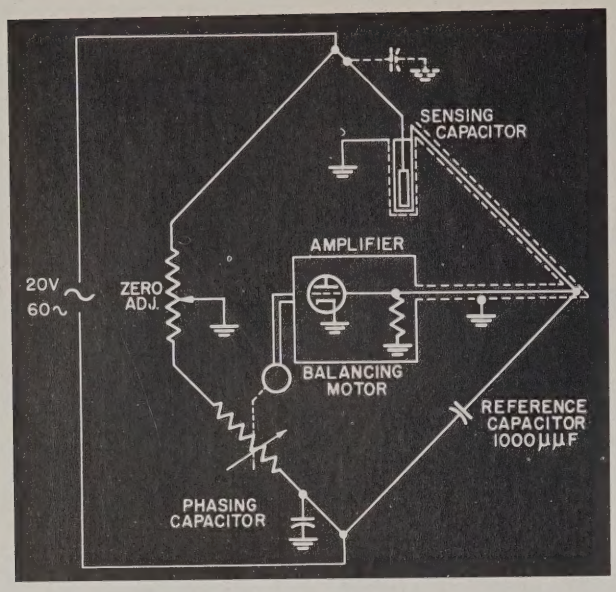
Design of the hydrogen and nitrogen liquefaction installations at the NBS-AEC Cryogenic Engineering Laboratory at Boulder, Colorado, introduced a number of new and complex engineering problems. (*NBS Technical News Bulletin, Volume 37, p. 132, October 1953*). One such problem was the maintenance of the liquefied gas levels in various parts of the system. The problem called for a gage that would not only measure the level but would control suitable machinery to admit new gas to the system to replace the liquid drawn off. Moreover, the materials used in the construction of the device had to retain their structural characteristics at temperatures near absolute zero.

A number of instruments involving different physical principles were considered. Buoyancy mechanisms, in which the position of a float is telemetered to the outside of the system, were rejected because of the difficulty of applying them to liquid hydrogen with its specific gravity of only 0.07. Hydrostatic devices that measure the pressure differential between the surface and the bottom of the liquid column were unsuitable because of their low sensitivity when used with liquids of low density. Thermometric devices, measuring the steep temperature gradient at the liquid-vapor interface, are not only inherently inaccurate because of the small temperature differential at the interface but tend to be sluggish in operation as well.

A satisfactory solution proved to be an electrical capacitance gage—a vertical cylindrical capacitor whose capacitance is a linear function of the height of the liquid within it. As finally developed by the Bureau, it is a reliable, precise indicator that can be used interchangeably with nitrogen, oxygen, hydrogen, or helium. The capacitance type of gage has no moving parts, and measurement of liquid level reduces to a relatively convenient electrical measurement. Its chief disadvantage lies in the need for electronic circuitry of fairly high sensitivity.

The NBS instrument consists of two distinct units: a sensing capacitor and an indicator-recorder-controller unit. The sensing capacitor forms one element of an a-c bridge whose output indicates and records the electrical capacitance and thus the liquid level. The bridge output also controls a pneumatic valve that admits more liquid to the system when the level falls below a particular point. The same basic recorder with its adjustable sensitivity will cover different ranges and will serve for liquids with different dielectric constants when used with an appropriate sensing capacitor. The same instrument can be used to indicate a span of 30 inches of liquid nitrogen in a 4½-foot dewar, 36 inches of liquid nitrogen in a 7-foot dewar, and 13 inches of liquid hydrogen in a 7-foot dewar. The dimensions of the sensing capacitors are different in each case.

The sensing capacitor consists of three concentric cylinders. The outer one is a grounded shield while the two inner cylinders form the active part of the condenser. The two outer cylinders are connected by a coaxial cable unit to the indicator, and the innermost is connected by an unshielded lead. The three-wire circuit is advantageous in that the system is largely independent of cable length as well as small impedance



Circuit used in liquid level indicator. A change in capacitance of the tank resulting from a change in the liquid level unbalances the bridge. Bridge is rebalanced by a motor driving a slider on the slidewire resistor, and at the same time the level is recorded on a chart.

changes caused by the effects of temperature and moisture cycling. The cable capacitance appears across the terminals of the amplifier, while the stray capacitance to ground of the central cylinder appears across one arm of the bridge and can be compensated by the phasing capacitor in the opposite arm. The stray capacitance thus enters less directly into the bridge balance and can be taken into account in the zero balancing.

A change in the capacitance of the sensing unit unbalances the bridge. The bridge output or signal voltage may then be reduced to zero by adjustment of a slidewire resistor to the point where the bridge is again balanced. The position of the slider is linearly related to the capacitance of the sensing unit and therefore to the liquid level. The liquid level thus determined is indicated by a pointer on a 25-inch scale and is also recorded on a 12-inch-diameter chart.

The rebalancing operation is automatic. The detector used here is a phase-sensitive amplifier whose output is determined by the amplitude and sign of the capacitive unbalance. The amplifier output energizes a two-phase induction motor, which drives the slider on the resistor wire, restoring the bridge to balance.

The instrument is easily adaptable for automatic control. In its intended application at the NBS-AEC Cryogenic Engineering Laboratory, the system provides a controlled air pressure, either directly or inversely proportional to the liquid level, for operation of a pneumatic valve in the tank inlet line. Thus, the liquid level in the tank may be held at any pre-selected point. An air relay valve of the on-off type is connected in series with the controlled air line to provide optional on-off or proportional control of the air inlet valve. The control mechanism is now being used at the Boulder laboratory to maintain a constant level of liquid hydrogen in the liquefier receiver by having it operate a throttling valve that adjusts the pressure forcing the liquid hydrogen through the transfer line to the external storage vessel.

In view of the wide range of temperature at which the sensing capacitor is used, it was necessary to choose materials that retain both their electrical and mechanical characteristics from room temperatures to the extremely low temperatures of the liquefied gases. It was also important to select tubes of low thermal conductivity in order to minimize the heat leak into the tank. Monel was therefore used in the fabrication of the tubes, and Teflon for the insulating spacers. The capacitor was constructed to be gas-tight to avoid observation errors that might be caused by moisture condensing between the plates and to provide a pressure seal.

A polyvinylformal coating on the innermost tube prevents sparking that might occur on accidental contact between the tubes. This precaution is taken to reduce the explosion hazard that might be present when using the instrument with liquid hydrogen. As a further safety precaution, the circuit design limits the maximum peak voltage across the sensing capacitor to 30 volts.

The sensitivity of the instrument is such that a capacitance change of 10 $\mu\mu$f corresponds to full-scale deflection on a scale length of 25 inches. This corresponds to approximately eight inches of liquid helium. Since the dielectric constants of liquefied gases are somewhat temperature-dependent, it is necessary to make appropriate correction if the instrument is used at temperatures other than the one for which it is calibrated. The correction is as much as 10 percent in some cases. The zero adjustment permits the use of tanks with empty capacitances from 120 $\mu\mu$f to 4000 $\mu\mu$f. With empty capacitances less than 600 $\mu\mu$f, the span is adjustable from 10 $\mu\mu$f to 200$\mu\mu$f.

The wide capacitance measuring range permits the use of a variety of sensing capacitors and makes the instrument adaptable to liquids having low dielectric constants. Using a sensing capacitor of appropriate design, liquid levels can readily be detected when the dielectric constants of the liquid and vapor states differ by as little as 0.05. It is possible to expand selected portions of the range through suitable design of the cross section of the sensing capacitor. By the same method, the scale may also be made nonlinear in any desired fashion.

The accuracy of the NBS liquid-level indicator depends on the uniformity of construction of the capacitor and on the precision with which the liquid surface can be defined in view of the boiling, agitation, and capillary effects frequently present. Tests made with liquid nitrogen and with carbon tetrachloride in the sensing capacitors show an accuracy and linearity within 1 percent.

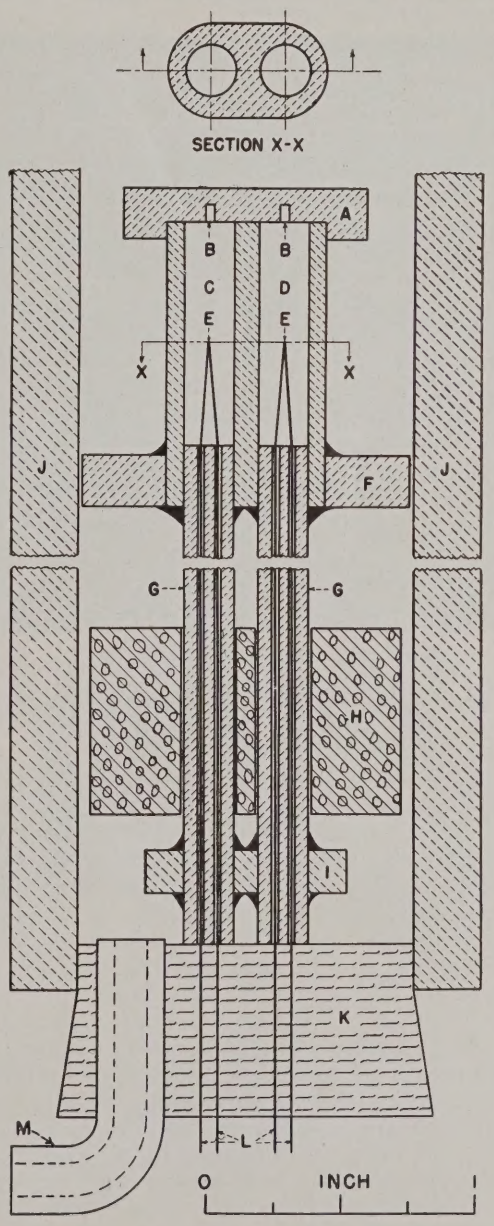
Properties of Foreign and Domestic NATURAL GRAPHITES

NATURAL FLAKE GRAPHITE is an essential ingredient for the crucibles widely used by foundries for melting nonferrous metals. Because this type of graphite, normally imported from Madagascar, is classified as a strategic mineral, it is being purchased for storage in the national stockpile. An earlier investigation by the National Bureau of Standards indicating that certain domestic graphites are fully as good as the traditional imported minerals has recently been extended to obtain complete technical data on the properties of 11 natural graphites from various domestic and foreign sources. This investigation, conducted by L. Mackles, R. A. Heindl, and L. E. Mong of the NBS refractories laboratory, will aid in the preparation of a more effective specification for governing the quality of this commodity, whether it be procured from Madagascar or from other sources that may develop in the future.

The sources of the graphites included in the study are Alabama, Pennsylvania, Texas, Madagascar, Kenya, Ceylon, Korea, Canada, Mexico, Bavaria, and Mozambique. The properties determined were those important in the successful use of the graphites for crucible manufacture—chemical composition, thermal reactions, surface area, and the refractoriness of the ash. The chemical composition is useful to indicate the chemical reactions between the graphite ash and the bond clay in crucibles and also between the ash and the molten metal and its slag. The refractoriness of the ash indicates the temperature at which the ash softened as a result of fusion. It was thought that the thermal reactions might aid in identifying minerals present in the graphite before heat treatment and also indicate physical changes of the graphite itself. The surface area measurements were intended to give a measure of the compactness of the graphite grains or flakes.

The ash of the graphites ranged from a low of 1.62 percent for that from Canada to 34.8 percent for that from Mozambique. However, the high ash of the latter was an exception because the other graphite ashes ranged below 16.0 percent. The remaining major constituents were essentially the same for all the graphites and no "tag" elements were found that might identify the source of the graphites. The percentages of the elements were, however, different. The silica-alumina ratios ranged from 2.0 to 10.9, the total alkali from 0.4 to 7.8 mole percent and the total alkaline earth from 0.6 to 43.6 mole percent.

The refractoriness of the ashes of the graphites ranged from a pyrometric cone equivalent of 5 (1,180° C) to a P. C. E. of 28 (1,615° C). Crucibles manufactured from Bavarian graphite, the ash of which has a P. C. E. of 5, have a life in the foundry equally as good as that of crucibles manufactured from either Madagascar or Alabama graphites, the ashes of which have a P. C. E. of 27. This indicates that the refractoriness of the ash is no criterion for judging the

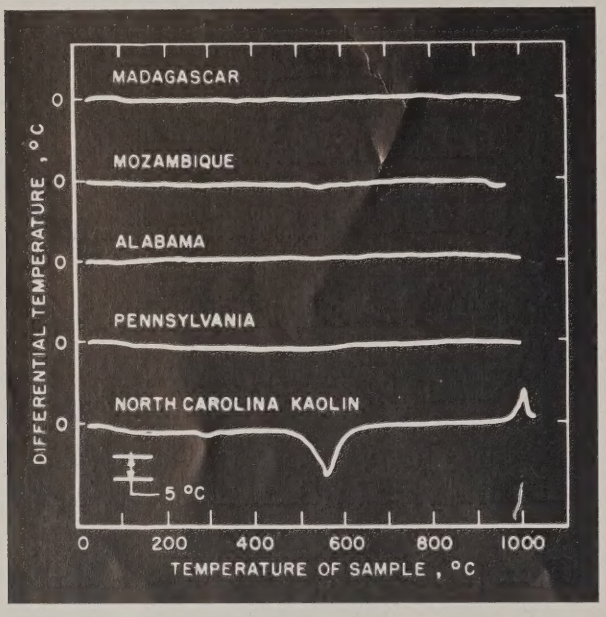


Sectional view of the apparatus used by the Bureau for differential thermal analysis of 11 graphites from foreign and domestic sources. (A) alumina cap; (B) vents; (C) sample compartment; (D) reference material compartment; (E) thermocouple junction; (F) centering ring; (G) thermocouple insulators; (H) diatomaceous earth heat insulator; (I) alining member; (J) quartz tube; (K) rubber stopper; (L) thermocouple leads; (M) glass tube for atmospheric gas connection (a similar tube is also provided at the top end of the quartz tube, J).

quality of a graphite for use in crucible manufacture. This is probably due in part to the fact that the clays added as a bonding material combine with the small percentage of ash to form inorganic mixtures that may have a refractoriness much higher than the P. C. E. of the ash and also much higher than the temperature at which the crucible is used.

The data obtained from differential thermal analyses in air atmosphere were not readily reproducible. The curves resulting from the tests indicate not only the temperature differences caused by the oxidation of the graphite but also any other heat effects occurring in the sample. The rate of burning can be determined quantitatively by other methods and should therefore be eliminated from the thermal analyses. There was no evidence of combustion when nitrogen was used as the atmosphere for the sample container. The curves resulting from the tests gave no indications of thermal reactions for any of the graphites with the exception of that from Mozambique. No thermal effects were expected for the graphitic material since no crystalline changes in graphite have been reported for the temperature range 20° to 1,000° C used in these tests. The small thermal change occurring in the graphite from Mozambique indicated that more than 10 percent kaolinite may be present and the analysis of the ash supported this premise.

Differential thermal analysis curves for two foreign and two domestic natural graphites heated in an atmosphere of nitrogen. The North Carolina kaolin curve indicates the sensitivity of the apparatus.



The total surface area of the graphites in the "as received" condition ranged from 0.34 to 26.50 square meters per gram. The upper value of the range was noted for the graphite from Mexico and is an exception because all the graphites have a surface area less than four square meters per gram. The graphites from Canada, Kenya, and Mozambique in contradistinction to that from Mexico are quite solid in makeup. The graphites from Alabama, Pennsylvania and Madagascar fall within the narrow range of 2.20 to 3.47 square meters per gram. Because high quality crucibles are obtained from these three graphites, the surface area values obtained may have some significance. The surface areas of the graphites were determined also after heating them at 400° C. Such heating would tend to drive off any residual flotation oils that might interfere with the sorption of the nitrogen gas necessary in this test. The surface areas of the graphites from Madagascar, Alabama, and Pennsylvania increased significantly after the heat treatment whereas the others remained unchanged or changed only slightly.

For further technical details, see Chemical analyses, surface area, and thermal reactions of natural graphite and refractoriness of the ashes, *by L. Mackles, R. A. Heindl, and L. E. Mong, J. Am. Ceram. Soc.* **36**, *No. 8, 266 (August 1953).*

Bleach Resistance of Porcelain Enamels

A CURRENT investigation by the Bureau indicates that common household bleaches, if the bleach manufacturer's directions are not followed, may have a significant and hitherto unrecognized deleterious effect on porcelain-enameled sinks and laundry tubs. J. R. Crandall, J. C. Richmond, and W. N. Harrison of the NBS enameled metals laboratory made the finding in the course of an investigation to determine how well results of standard laboratory tests of porcelain enamels correlate with actual service experience. In view of the extensive use of household bleaches by housewives, the Bureau's finding suggests the possible desirability of adoption of a standard laboratory test that would help manufacturers and users select those porcelain enamels that will be least affected by bleaches.

Techniques for predicting service behavior on the basis of laboratory measurements are of considerable value to porcelain-enamel manufacturers. NBS, in cooperation with the Porcelain Enamel Institute and various manufacturers, has been working on the development of suitable test methods for a number of years. The need for a comprehensive field study to determine the correlation between present laboratory tests and deterioration in actual service has been recognized for some time. An adequate study of this type is necessarily a somewhat ambitious undertaking, however, and nothing had been done along these lines until NBS, with the encouragement and cooperation of industry, began the present investigation.

Subjects of the Bureau's study have been porcelain-enameled appliances in public housing projects in four locations, the locations having been selected for their extremes of water characteristics. The complete program includes (1) porcelain-enameled table tops, (2)

apartment-size gas stoves with enameled tops, doors, and oven linings, (3) enameled kitchen utensils, and (4) combination sink-and-laundry-tub units with which the kitchens in these housing projects are equipped. A number of different enamels are represented: the sink-laundry units are variously coated with any one of five acid-resistant (class AA) or two nonacid-resistant (class D) enamels. Duplicates of each piece of service equipment were retained at NBS for laboratory study.

Standard tests applied to the duplicate laboratory specimens have included the surface abrasion, scratch, gouge, and acid resistance tests of the Porcelain Enamel Institute and the impact, thermal shock, and boiling acid tests of the Enameled Utensil Manufacturers Council. Periodic field inspections of the units in service have included visual observations, measurements of loss of surface gloss by means of a Hunter photometric unit, measurements of enamel thickness by means of the Brenner magnetic thickness gage, and the making of plastic replicas of certain portions of each enamel surface. The loss-of-gloss measurements and the plastic replicas give particularly valuable indications of the degree of deterioration of the enamel surfaces.

These plastic replicas are easily made in a few seconds simply by pressing a thin 4 by 4 inch sheet of ethyl cellulose, moistened with 20-acetone 80-toluene solvent, against the enamel surface. Fine texture detail is faithfully recorded on the solvent-softened ethyl cellulose sheet, which dries and hardens almost immediately. In the course of the present study the Bureau has accumulated a unique and valuable file of thousands of replicas of the condition of various enamel areas after successive periods of service.

In the first 25 months of the study only the sink-laundry units showed sufficient wear in service to warrant analysis of data. These data indicate that existing standard tests do not adequately simulate all of the important causes of wear deterioration of porcelain enamels in actual service.

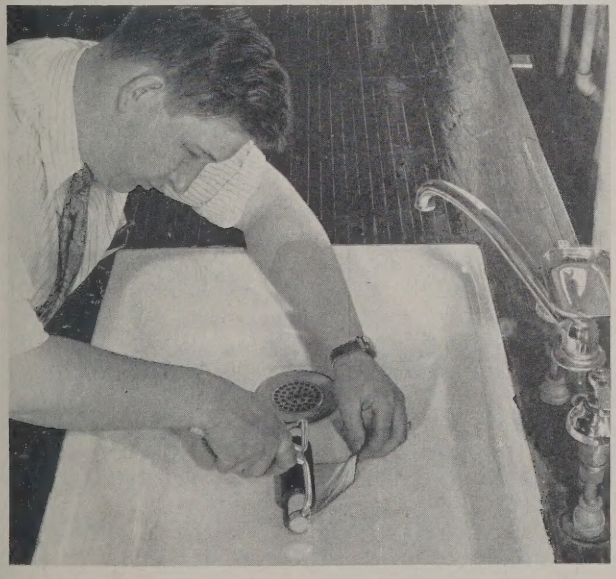
In the case of the laundry-tub bottoms, the correlation was particularly poor between enamel deterioration in service—as indicated by the loss-of-gloss measurements and by the plastic replicas—and the standard laboratory tests. It has been observed, however, that most of the housewives at the test installations apparently made generous use of household bleaches of the sodium hypochlorite type without diluting them as recommended; and these bleaches would naturally be in contact with the laundry tub bottoms to a greater extent than with the other enamel areas studied.

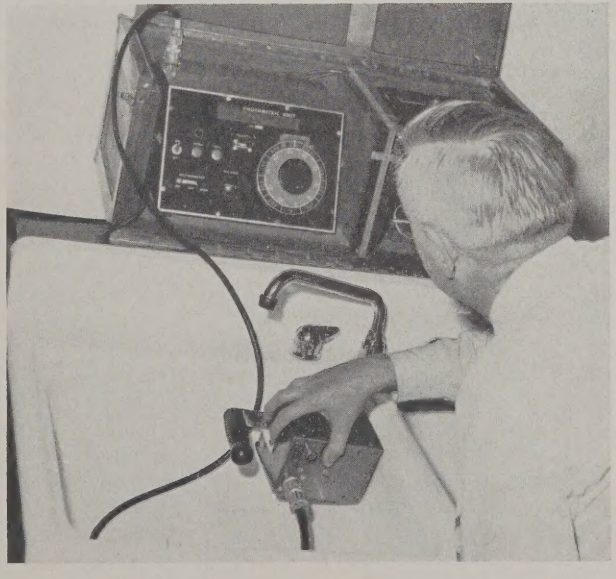
To investigate the possibility that these bleaches might be a factor in enamel deterioration, various enameled specimens were exposed in the laboratory to a full-strength commercial household bleach (containing about 5¼ percent of sodium hypochlorite) at 115° F for various lengths of time. Loss of gloss in varying degrees resulted, and the degree of gloss-loss correlated well with the observed gloss-loss of the same enamels in actual laundry-tub service.

Because it was the apparently widespread use of bleaches in stronger-than-recommended form and for longer-than-recommended soaking times that had attracted attention, the Bureau's laboratory work was centered on the effects of full-strength bleach. The findings do not mean that significantly deleterious effects are to be expected from the use of household bleaches in the manner generally recommended by reputable bleach manufacturers.

For further technical details, see Correlation of laboratory and service data on porcelain enamels, *by James R. Crandall, Proceedings of the 14th Annual Porcelain Enamel Institute Forum (1952), 166.*

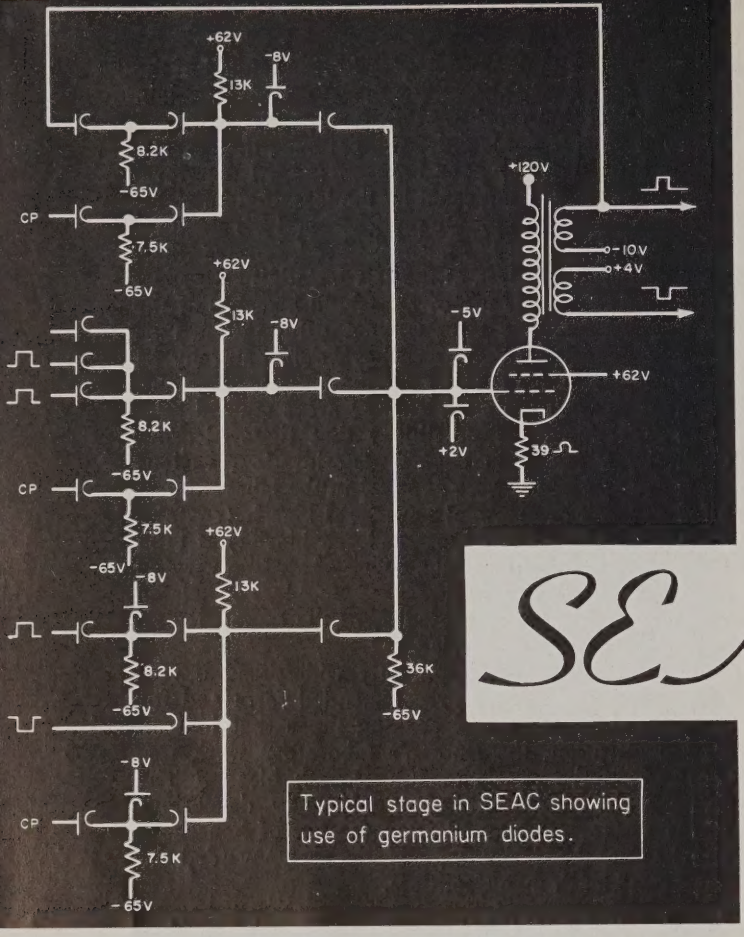
Plastic replicas of porcelain enamel surfaces are made by rolling a solvent-softened sheet of cellulose acetate against the enamel surface (left). This technique, developed by NBS several years ago, is proving valuable in field study of deterioration in service of porcelain-enameled equipment installed in kitchens of housing projects. Making a loss-of-gloss measurement (right) on the enamel surface of a combination sink-and-laundry-tub unit.





SEAC was completed by NBS in May 1950, under sponsorship of the Office of the Air Comptroller, Department of the Air Force. Since that time it has been in useful operation for more than 25,000 hours on a 'round-the-clock seven-day week. Not only has it been utilized for solution of extensive and diverse mathematical problems, but continued engineering has expanded the installation into a far more powerful tool.

SEAC IMPROVEMEN



Typical stage in SEAC showing use of germanium diodes.

SEAC—the National Bureau of Standards Eastern Automatic Computer—is an automatic high-speed digital computer operating at a one-megacycle repetition rate. The machine is predominately serial in nature and uses a binary number representation. Both instruction words and number words consist of 45 binary digits, which are equivalent to approximately 13 decimal digits. When the machine was first put into operation, it was capable of performing 11 different types of arithmetic and logical operations. The original memory consisted of 512 words of acoustic delay-line storage, and all of the input-output devices were modified Teletype equipment.

Engineering Improvements

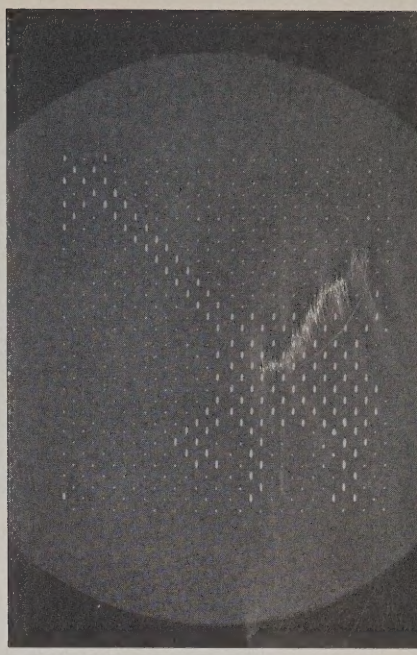
During its three years of useful activity, approximately 25 percent of SEAC's operating time has been devoted to the continued expansion of the machine. A measure of this expansion is the increase in the number of vacuum tubes from approximately 750 to 1,300 and in the number of germanium diodes from 10,500 to 16,000.

An experimental electrostatic memory has been installed to provide an additional 512 words of internal storage in its 45 cathode-ray tubes. As this memory is arranged to operate in the parallel mode, the access time to information contained within it is considerably reduced, thereby increasing the computation speed over that possible with the mercury memory. External magnetic tape and wire units have been added as aids to the computer on problems that require auxiliary memory capacity or considerable input-output operations. The magnetic units store coded subroutines, instructions, and numerical data on problems too lengthy to be stored in the machine's internal memories. One such device can store 24,000 words on a 1,200-foot magnetic tape.

Five additional mathematical operations have been incorporated into SEAC to facilitate the solution of complex problems and to provide optimum use of the external storage facilities. Another convenience that has been added is a facility for monitoring automatically the operations currently being performed. When this feature is called into use by setting a switch on the control console, the machine automatically prints out check points according to the coded instructions included in the program. The operator can observe the progress of the problem by monitoring the problem step-by-step and can make any desired changes while the problem is still in the machine.

An alternate instruction system using a three-address mode of operation has also been installed. When the four-address system originally built into the machine is used, the memory location of the next instruction to be performed is found in the instruction word currently being executed. In the new three-address system, however, the computer simply proceeds through a list of instructions consecutively located in the memory. An exception to this convention is available through a "comparison" operation, wherein the next instruction address, under certain circumstances, is chosen from

IN a computer memory improvement program, the NBS computer laboratory initiated the design of a new cathode-ray storage tube adapted specifically to the needs of the Williams electrostatic memory system. In addition, the laboratory has applied techniques that have overcome the original difficulties. This experience with the Williams system has yielded increased reliability of the SEAC memory.

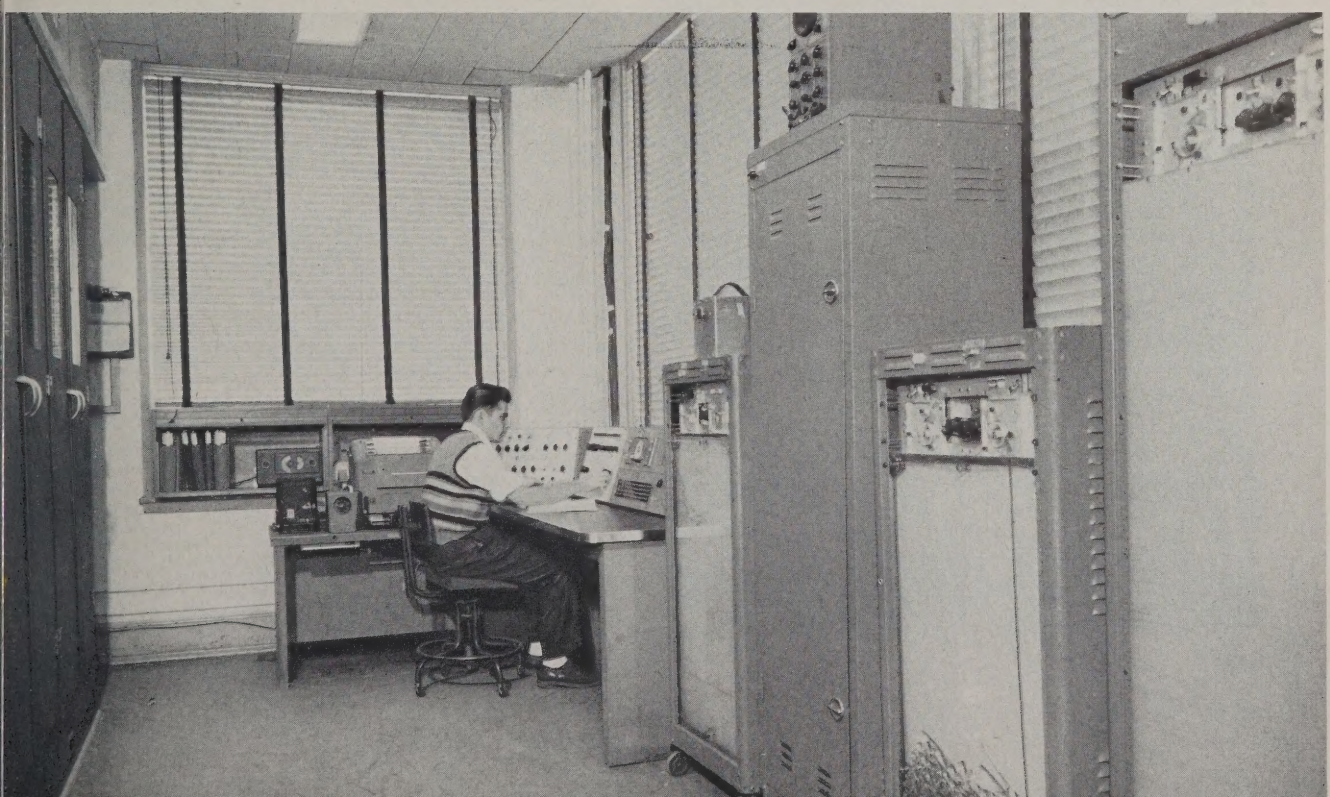


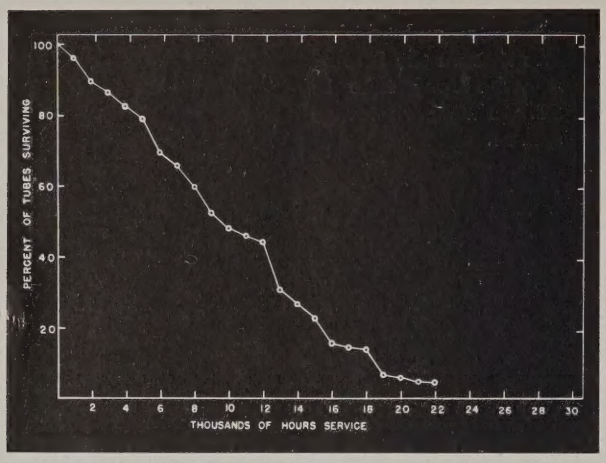
Demonstration pattern of dots and dashes like that on the face of a cathode-ray tube in SEAC's Williams storage system.

NCREASE COMPUTING POWER

the current instruction. The special advantage gained from the three-address system is the relative address feature. This is a convenience in coding problems because it enables the programmer to designate any memory position either absolutely or by reference to other memory positions whose exact locations may vary.

EAC computing room. Control console is at the far end of the room, and the computer proper is at left. To right are several of the external magnetic-tape storage units.





Survival curve of the type 6AN5 tube used extensively in SEAC, based on the service of 1,775 tubes.

A number of circuit and equipment innovations have been included in the SEAC development program, in order to evaluate the reliability and serviceability of techniques that were highly promising but unproved. Examples in this area are the extensive use of diode switching and the achievement of a-c coupling by using pulse transformers for highly variable duty factor service. Success with these techniques made practical the use of vacuum tubes exclusively for power amplification rather than as gating devices.

Tube and Diode Performance

Each of SEAC's more than 50,000 components must function reliably every microsecond during the many hours that a problem is in progress. Component specifications were prescribed that permit considerable deviation from the design-center values of the circuits. However, a brief excursion of a single unit beyond these prescribed limits may cause computer malfunction. It was thus desirable to make statistical studies of the components, especially tubes and diodes, to determine their behavior in operation.

Extended operation of SEAC has provided a means for determining the long-term reliability of large samples of tubes as well as the germanium diodes used in the switching circuits. More than two-thirds of the tubes used in the computer are of a single type—the 6AN5. Since a standard pulse repeater stage using the 6AN5 is the basic building block of the NBS computer, it was necessary to study these tubes so that more detailed specifications for them could be determined. The use of a single type of amplifier stage to perform extremely varied logical functions was a new concept with the initial design of SEAC, and the usefulness of this concept depended on how reliably the basic components—tubes and diodes—would operate in actual use.

In conjunction with the regular maintenance routine, an operational procedure was set up to keep a record of each tube, particularly of the service life. A tube is removed from the machine whenever it approaches the tolerance limits prescribed by machine operation because operation takes precedence over study of tube characteristics.

During the three years that SEAC has been operating, approximately 2,500 type 6AN5 tubes have been used in the machine; 1,300 have been rejected for various reasons. Since rejections are made almost exclusively during the machine maintenance periods, operation failures of the 6AN5's in SEAC have been very few except during an early period of excessive heater voltages. During one 15-month interval, it was necessary to replace only 18 tubes during machine operation time. Approximately 55 percent of all rejections were made on the basis of low emission and undue heater sensitivity.

It must be emphasized that a stringent requirement was placed on heater sensitivity because of the wide variation in filament voltage throughout the computer during its early period of operation. The requirement is that a reduction from 6.3 v to 5.7 v in filament potential will not cause more than a 25 percent decrease in plate current. Thus, many otherwise usable tubes were rejected before they caused trouble. As a result, tube survival curves and cumulative rejection curves are weighted heavily on the side of heater sensitivity although this requirement is less important than other reasons for rejection.

Other reasons for rejection were mechanical damage in handling, grid-cathode short circuits, open circuits, and microphonics. After 8,000 hours' operation, heater sensitivity was almost the sole cause for rejection. Studies of the the data obtained show that in one group of tubes, those used in the arithmetic and control units of the computer, the median life is approximately 12,000 hours. The median life of 6AN5's in the entire machine is 8,700 hours.

The basic measure of reliability of germanium diodes in the computer is the rate at which diode failures cause machine malfunctioning. For a two-year period through December 1952, covering 15,819 hours of operation, the total failures amounted to 0.3 percent of the population under study, or 0.02 percent per thousand hours. This does not include diodes used in the electrostatic memory.

Operational failures of diodes in SEAC are few and are offset by preventive maintenance replacements. These replacements did not interfere with the mathematical assignments of the machine as they were made during regular maintenance periods. Each diode was tested under d-c conditions about once every six months for excessive forward resistance and excessive back current. From December 1951 to December 1952, 848 diodes were replaced out of one group of 12,000 because they failed to meet the specifications, although they were not causing trouble.

So far, all diodes have been required to meet a single set of specifications. General studies of diode behavior indicate that if separate specifications had been set up for the diodes used in the less critical circuit positions, the majority of diodes removed could have been left

in the machine for at least another year. Consideration of different standards for different applications of diodes promises greater reliability in future computer design.

Problems Solved

In a typical month's operation, SEAC may be engaged on as many as 50 different unrelated problems from various fields of science. The time for running a problem may vary from a few minutes to many hours, depending on its nature and complexity.

Two of the problems undertaken by SEAC have actually been very large, with many ramifications. Together they have used 57 percent of the 11,000 hours "good time" (i. e., scheduled time exclusive of engineering development, maintenance, or out-of-order times) between September 1, 1950, and May 1, 1953. One of these projects is the theoretical linear programming work for the Office of the Air Comptroller, which sponsored the development of the computer. The object of this problem is to devise a purely mechanical process which will replace the thousands of individual human decisions involved in a major management and production-scheduling program. The other large project was one for the Atomic Energy Commission.

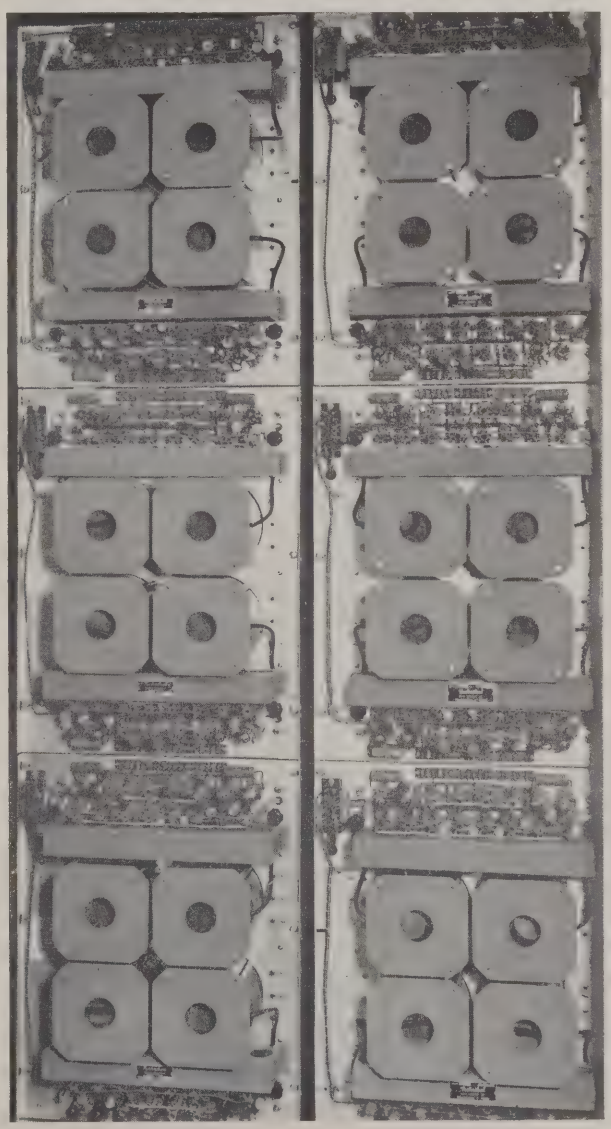
In the remaining 43 percent of the good time, approximately 84 projects have used the computer, and about half of these were still in progress as of May 1, 1953. In this group the computation of Loran tables was the largest single project. SEAC has been utilized in the preparation of many other mathematical tables. Jacobi elliptic functions, gamma functions for complex arguments, spheroidal wave functions, Coulomb-wave functions, and confluent hypergeometric functions are typical of this kind of activity.

SEAC has an auxiliary memory of the Williams cathode-ray tube type. Half of the memory is shown here. In this type of memory, information is stored as charged "dots" or "dashes" at a great many positions on the faces of the tubes.

Besides the tabulation of many mathematical functions, SEAC has been used to attack other problems in physics and engineering. An example is the problem of relative abundance of the elements, which involved the solution of a twenty-seventh-order system of ordinary differential equations relating to the neutron-capture theory of the formation of elements in the universe. Another example is the solution of second-order nonlinear differential equations describing the trajectories of electrons through a cavity. SEAC has also computed the complicated simultaneous nonlinear equations necessary for describing shock waves that follow an explosion and the performance of explosives of various chemical compositions. Other tasks undertaken by the computer have concerned such varied matters as electronic circuit design, optical lens calculations, wave functions for helium and lithium atoms, and naval architectural design involving the wave resistance of ships.

Operating Efficiency

SEAC's operating efficiency is defined as the sum of problem-solution time, code-checking time, and idle-in-order time divided by the total time assigned to computation. "Down-time" is the portion of scheduled time in which production was lost because of (1) machine malfunctioning, (2) diagnosis and correction of the malfunctioning, and (3) recomputation of problems not completed as a result of machine difficulties. The efficiency for the best quarter was 82 percent, and during the week of October 27, 1952, an efficiency of 93.5 percent was achieved for the 124 hours of assigned time. The average, from the time of initial operation to the present, has been 72 percent. A variation of as much as 20 percent between three-month periods is a reflection of the continued expansion and engineering performed on SEAC.



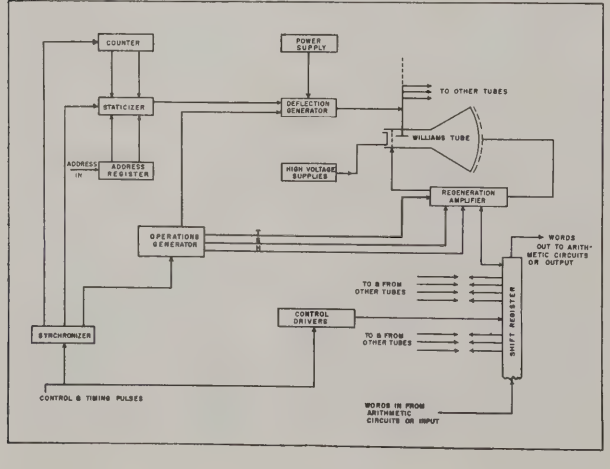
ELECTROSTATIC MEMORY IMPROVEMENT

Named for its originator, Prof. W. C. Williams of the University of Manchester (England), the Williams electrostatic storage technique uses ordinary cathode-ray tubes of the oscilloscope type to store information in electrical coded-pulse form. The pulses are stored as "dots" or "dashes" (corresponding to the binary "zero" and "one") at a large number of positions on the face of the tube in a regular pattern known as a "raster". When information is to be stored, the tube's electron beam is directed to various positions on the raster. The beam remains at each position for either a very short interval (a fraction of a microsecond) or a longer interval (several microseconds), providing two configurations (dot or dash) of electrostatic charge.

With the completion of SEAC in early 1950, a memory-improvement program was undertaken at NBS aimed mainly at increasing the speed of computation and extending the problem-solving capacity of the computer. The first result of this work was an experimental memory of 45 cathode-ray tubes, each storing 512 binary digits of information. Completed and in operation by February 1951, the electrostatic memory supplements SEAC's regular acoustic delay-line memory and doubles the total information storage capacity.

The memory development program has involved various aspects of the design, test, and evaluation of electrostatic systems. The study has proceeded along five major lines: (1) investigations to develop the theory of Williams-type storage, (2) development of circuitry for a parallel memory system, (3) development of testing methods and equipment to determine the suitability of cathode-ray tubes for storage purposes, (4) cooperation with other groups interested in electrostatic memories to obtain improved storage tubes, and (5) devising of methods to overcome the deficiencies of standard cathode-ray tubes.

Block system of the Williams electrostatic memory.



Attempts at analysis of electrostatic storage indicate that rather complicated phenomena occur within the cathode-ray tube. As developed at the National Bureau of Standards, the theory of electrostatic storage is based on the original propositions advanced by Professor Williams, but it includes modifications by other workers in the field (see note, p. 13) and is supplemented by information obtained from the Bureau memory-improvement program. Until recently, this complex theory considered the mechanism of storage as being analogous to the operation of a space-charge-limited diode. The cathode in this case is an electron-bombarded spot on the phosphor screen that emits secondary electrons, and the anode is the aquadag coating on the inside of the cathode-ray tube. The NBS contribution, called the *triode theory*, considers that an added lower-potential region surrounding the spot is equivalent to a coplanar grid. The action then becomes somewhat analogous to a three-element tube. While the NBS theory is still tentative, it does explain certain important effects caused by changes in the potential of the area adjacent to the region of primary electron bombardment.

Charge is automatically restored to full strength at regular intervals. When the information stored at a particular location is wanted, it can be obtained very rapidly by deflecting the tube's electron beam to the point of interest on the face of the tube. The output signal is coupled capacitively from the phosphor surface inside the tube to a metal screen on the outside face, and is amplified and recognized through suitable circuitry as a dot or a dash.

Originally it was thought that Williams-type storage could be accomplished in this country using standard commercially available cathode-ray tubes. However, experience showed it was necessary to discard about four out of every five tubes from production lots because they were not suited for use in the memory.

Two lines of attack on the problem of improved tubes have been emphasized in most electronic computer laboratories. The first approach has been an effort to minimize the limitations of available tubes; the second has sought to obtain an improved tube. Both approaches have recently yielded satisfactory results.

One of the major tube problems has been the presence of minute areas on the phosphor surface which do not store information. During operation of the memory these "blemishes" must be avoided, or the tube discarded. It is difficult to avoid these nonstoring spots when many tubes are operated in parallel: if the raster in one tube is shifted to miss a blemish, the raster in another tube may coincide with one. Computer operation then becomes unreliable, for the memory gives false information.

Test circuitry has been developed at the NBS laboratory that will locate the blemishes on the face of a tube and measure the degree to which these bad spots will not store. Use of this equipment determines a tube's suitability for SEAC's memory. Techniques for removing blemishes have been refined to the extent that

now only 20 percent of new 3-inch-diameter tubes are rejected for this reason, compared to the former rate of 80 percent.

A second major difficulty encountered in Williams storage is the obliteration of the stored charge at one spot by the splash of the secondary electrons emitted from the neighboring spots during read-write operations. The number of interrogations of near-by spots that may be made before regeneration is required is called "read-around-ratio". A low read-around-ratio may be improved either by the use of operating methods that place serious limitations on the use of the memory or by improving the intrinsic properties of the tube in this respect.

The splash effect is mostly a function of gun design. To mitigate this difficulty, manufacturers were approached regarding improved designs, and several trial tubes were ordered, based on Bureau design suggestions. These were tested at NBS and other computer laboratories. The results were so encouraging that a conference was called with computer specialists from other government agencies and government associated activities. This led to an agreement on specifications for a standard computer tube, and small-scale production of this tube has begun.

The Williams memory installed in SEAC is now engaged in the solution of mathematical problems that require 512 information words in addition to the 512 words already provided by the acoustic delay-line memory. During the period from June 1 to October 1, 1953, it was used on 67 different occasions with a total good time in excess of 115 hours. These error-free runs ranged from about 10 minutes to 9 hours.

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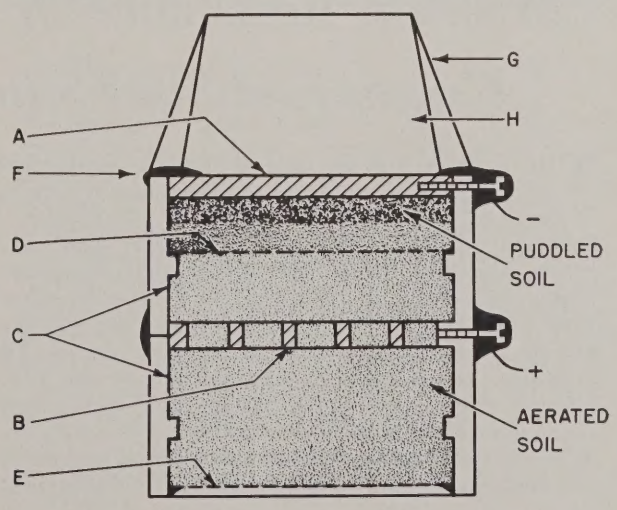
Laboratory Measurement of CORROSION IN SOILS

A RECENT STUDY by the Bureau has shown that reliable data on the corrosion of ferrous metals in soils of various types can be obtained in the laboratory in a period of six months. Usually field tests lasting 10 years or more are required. In the NBS investigation, which was conducted by W. J. Schwerdtfeger of the NBS corrosion laboratory, corrosion was produced in small laboratory cells by differential aeration of metal disks in contact with soil within the cells. The results for 15 different soils showed good correlation with the corrosion observed on wrought specimens in long-term exposure tests. The technique used by the Bureau should thus provide a valuable basis for predicting the service of iron and steel structures exposed to various soils.

The corrosion of metals in many soils is attributed chiefly to differences in the accessibility of oxygen to the surface. Differences in oxygen concentration create differences in the potential of various areas, resulting in the flow of electric currents through the soil from the oxygen-deficient areas (anodes) to those areas (cathodes) receiving more oxygen. The laboratory corrosion cells used by NBS made use of this principle. Each cell consisted of a cylindrical Lucite enclosure containing two short-circuited disk-shaped electrodes of the same material, iron or steel. One electrode was solid, the other perforated, and they were separated by a layer of moist soil. The edges and one



Soil corrosion cell used for laboratory measurement of corrosion of iron and steel in various soils. (A) anode; (B) cathode; (C) Lucite cylinders; (D and E) stainless steel screens for holding soil in place; (F) Bitumen; (G) rubber band; (H) rubber stoppers.

face of each of the two electrodes were covered with bituminous paint. The layer of moist soil in contact with the coated side of the perforated electrode regulated the diffusion of air to the electrodes. The perforated electrode received a greater supply of oxygen than the solid one adjacent to which the soil was puddled, and therefore assumed a more positive potential.

If the corrosion of ferrous metals in all soils proceeded at a rate that was constant with time, weight-loss measurements made after a short arbitrary period of exposure should indicate relative rates of corrosion, assuming negligible cleaning errors. Actually, however, corrosion in soils may proceed at a rate proportional to time, or may sometimes cease entirely, depending on the type of soil. It was thus necessary to operate the laboratory corrosion cells for a sufficiently long period to produce effects comparable to those shown by field exposure tests.

In the NBS investigations, the corrosion cells were kept on short circuit for six months. During this time periodic measurements of cell current permitted study of the progress of corrosion with time. At the end of the period the combined weight losses of the two electrodes were taken as the measure of corrosion.

To evaluate the laboratory corrosion cell as a means for predicting corrosion in the field, samples of soil collected at 15 NBS exposure sites were used. The results were correlated with weight-loss measurements made on short lengths of steel and wrought iron pipe which had been exposed for 10 years at the same 15 localities. An empirical equation relating the laboratory and field data indicated that the laboratory measurements could be used to predict field weight losses with root-mean-square error of about ± 4 oz/ft^2 for corrosion rates ranging from 2.5 to 30 oz/ft^2 for the 10-year exposure period. Because the 15 soils covered the range of corrosivity of the soils of the United States, this empirical relationship may be applicable to any soil.

Because some underground structures, such as piping systems and storage tanks, usually fail as a result of pitting, this factor was also considered. Analysis of the field data showed a good correlation between weight losses and maximum pit depths on wrought ferrous specimens that had been exposed for 10 years at 58 NBS exposure sites. These data were then combined with the first empirical equation to obtain a second equation which can be used to predict, with an average error of ± 18 mils, the depth of the deepest pits occurring on wrought iron or steel buried for 10 years. For the prediction of weight losses and maximum pit depths on areas greater than the area of the field specimens and for periods of exposure other than 10 years, use was made of general equations relating weight losses and maximum pit depths with length of exposure and exposed area. Average values for the constants to be used in these equations were obtained.

It was found that the corrosion cell could detect significant differences between the corrosion rates of cast iron and steel, which are generally considered to corrode at about the same rate in soils. Thus, the cell might be used to study the effects of variables, including composition upon the corrosion rates of steels. It is also reasonable to expect that laboratory corrosion cells could be used to predict the corrosion of nonferrous metals—copper, brasses, lead, zinc and possibly aluminum—in various kinds of soils. Although measurements with the laboratory cell should not be considered as replacing field exposure tests entirely, it is unlikely that materials that corrode at the same rate in the laboratory would corrode at significantly different rates in the field. Hence, the corrosion cell should serve a useful purpose in the selection of materials for field exposure tests.

For further technical details, see Laboratory measurement of the corrosion of ferrous metals in soils, *by W. J. Schwerdtfeger, J. Research NBS* **50**, *329 (1953) RP2422.*

Corrosion Resistance of *Galvanized-Steel-Stitched Aluminum Alloys*

THE BUREAU, at the request of other government agencies, has investigated the corrosion resistance of sheets of unclad and aluminum-clad 24S–T3 aluminum alloy stapled together with galvanized steel wire. Stapled specimen sheets of this high-strength aluminum-copper-magnesium alloy (containing about 4½ percent copper and 1½ percent magnesium) were exposed in a marine atmosphere and in the tidewater. Results for exposure periods up to 37 months indicate that both types of sheet joined in this fashion have satisfactory corrosion resistance for service in marine atmospheres. Where the installation is subject to frequent wetting by sea water, however, only the "alclad" (aluminum clad) alloy appears satisfactory. The Bureau's study was conducted by Fred M. Reinhart of the NBS corrosion laboratory, under the sponsorship of the National Advisory Committee for Aeronautics, the Navy Bureau of Aeronautics, and the Air Force Wright Air Development Center.

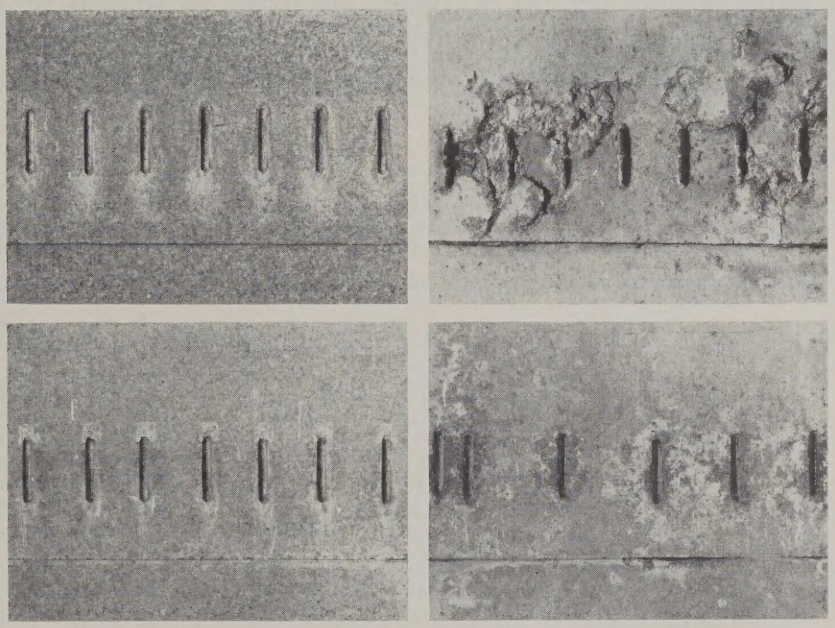
Galvanized-steel-wire stitching, or stapling, as a means of joining aluminum sheets has been used increasingly since early in World War II. Fast and economical, this relatively new method has given good results in the construction of non-load-bearing walls and partitions in the interior of aircraft. Although the joints are not inherently as leakproof as those made

by other methods, the use of suitable sealing materials can overcome this objection. Wire stapling of sheet metal is reported to have been extended more recently to non-aircraft applications, including interior panels in buses and in houses. Thermally insulated wall panels are readily fabricated by the stapling of layers of insulating material to the metal sheeting; a single stapling operation can fasten the insulation to the metal sheets as well as join the sheets to each other.

In the NBS work, stapled panels of each material (24S–T3 and alclad 24S–T3) were subjected to intermittent sea-water immersion by exposure in the tidewater. Other panels of each material were exposed in a marine atmosphere but not subjected to wetting. Panels were observed periodically and were removed for macroscopic and microscopic study after exposure periods of 6, 11, 22, and 37 months.

present, and the underlying steel had barely begun to pit. There were no corrosion products between the faying surfaces of the alclad sheets, indicating little if any crevice corrosion. Although most of the aluminum cladding had disappeared from the faying surfaces at 11 months, the core material had not been attacked even at 22 months. Only after 37 month's exposure did the core show pitting and—but only in one area—stress corrosion.

When the alclad and the unclad alloy were exposed in a marine atmosphere, there was very little corrosion of either, even after 37 months. The staples on both specimens were still coated with grey corrosion products, indicating that zinc or zinc-iron alloy layers were still present. None of the staples were significantly pitted. The faying surfaces of the 24S–T3 panel were slightly pitted, but no evidence of intergranular corrosion or stress corrosion cracking was found. The



Specimens of galvanized-steel-stitched sheets of aluminum alloy studied for corrosion resistance. Specimens at left were exposed 37 months to a marine atmosphere, those at the right to tidewater. Top specimens are plain 24S–T3 aluminum alloy, and bottom are aluminum-clad 24S–T3.

The unclad 24S–T3 panels exposed to tidewater deteriorated rather rapidly. After two months the zinc coatings on the steel staples were white with corrosion. After six months the zinc was entirely gone from the staples, which by this time were covered with dark adherent rust. Microscopic inspection at six months showed that directly underneath the staples the sheets had cracked by stress corrosion, the cracking having started at the faying (joined) surfaces of the sheets. By the end of 37 months the staples were badly rusted and pitted; and the sheets in the area of the staples had suffered severe crevice corrosion, intergranular corrosion, and stress corrosion cracking.

The alclad 24S–T3 panels stood up much better in the tidewater exposure. The attack on the zinc coating of the staples was much less severe. Even after 37 months some of the zinc-iron alloying layers were still protective aluminum layers on the alclad 24S–T3 sheets were pitted at a few areas of the faying surfaces, but in no case had the pits corroded to half of the thickness of the layers. Crevice corrosion was quite mild—there were only small amounts of corrosion products between the faying surfaces of the unclad panels and practically none between those of the alclad panels.

Because of the crevice corrosion that developed, in varying degrees, at the faying surface of the joints, the application of a protective coating to these surfaces appears to be desirable for maximum service life as well as for leakproofing of the joint. A nonabsorbing type of sealing compound or paint can be applied to the joints either during or after the joining operation.

For further technical details, see Exposure tests of galvanized-steel-stitched aluminum alloys, *by Fred M. Reinhart, NACA Technical Note 2299 (1951).*

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TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

January 1954 **Issued Monthly** **Vol. 38, No. 1**

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price, domestic, $1.00 a year; foreign, $1.35; single copy, 10 cents. The printing of this publication has been approved by the Director of the Bureau of the Budget, March 6, 1953.

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